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Gluonic Three Jet Production at Next to Leading Order [a]

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ABSTRACT

I report results from a next-to-leading order event generator of purely gluonic jet production. This calculation, performed in collaboration with Walter Giele, is the first step in the construction of a full next-to-leading order calculation of three jet production at hadron colliders.

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THREE JET PRODUCTION AT NEXT TO LEADING ORDER

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Introduction

In this talk I will discuss some results of a next-to-leading order event generator for hadronic three jet production. I will begin by briefly outlining the procedure for performing next-to-leading order jet calculations. I will then present a status report on the progress of this calculation.

Next-to-Leading Order Jet Calculations

The calculation of three jet production at next-to-leading order combines two-to-three parton scattering to one loop with Born level two-to-four parton scattering. Both of these contributions are singular. Only the sum of the two contributions is finite and physically meaningful. The one loop two-to-three parton amplitudes contain infrared singularities arising from the presence of nearly on-shell massless partons in the loops. The Born level two-to-four parton amplitudes are also infrared singular, diverging when one of the partons is very soft or when two partons are highly collinear.

The origin of the singularities concerns parton resolvability. If a parton becomes very soft, or if two partons are highly collinear, it becomes impossible to resolve all final state partons from one another. The four parton final state looks instead like a three parton final state. (In fact, of course, individual partons can never be resolved, and are only observed as jets of hadrons.) By imposing a resolvabilty criterion one can define an infrared region of phase space. By using asymptotic approximations of soft or collinear matrix elements[1] within that region, one can integrate out the unresolved parton and obtain effective three body matrix elements with poles that exactly cancel those of the one loop matrix elements.

This is known as the phase space slicing method.[2,3] The infrared region is of two partons labelled i and j is larger than s_{min}, the partons are said to be resolved from one another (although they may yet be clustered into the same jet), otherwise partons i and j are said to be unresolved from one another. If there is only one pair of unresolved partons i and j, then those partons are said to be collinear. If there is some parton i which in unresolvable from two or more partons $j, k, \ldots$, then parton i is said to be soft.

Using phase space slicing, the singularities are removed from the two-to-four parton scattering process and added to the one-loop two-to-three process, cancelling the singularities. However, since the boundary of the infrared region was defined by the arbitrary parameter s_{min}, the slicing procedure induces logarithmic s_{min} dependence in both sub-processes. The cancellation of the s_{min} dependence in the sum of the two processes provides an important cross check on the calculation.

The resolution parameter s_{min} is completely arbitrary and is independent of the jet clustering algorithm. This allows us to use a variety of jet algorithms and facilitates comparison with experiment. In principle, s_{min} can take any value, but in practice must lie within a finite range. If s_{min} is too large, it forces partons to be clustered that the jet algorithm would otherwise leave unclustered. If s_{min} is too small, the logarithms of s_{min} become large. The magnitude of the cancellation between the two sub-processes grows, requiring increased computer time to obtain the cancellation to a given statistical accuracy.

Progress Report

At this time, we have developed a working event generator for pure gluon scattering. We thus combine the one-loop virtual cross section for $gg \rightarrow ggg$ scattering[4] with the Born level cross section for $gg \rightarrow gggg$. This development is a significant step towards completing an event generator for the full three jet cross section at next to leading order, since all essential components such as phase space generators, jet clustering algorithms, phase space slicing, etc., must be working properly. In principle, the completion of the project simply involves adding the remaining matrix elements to the existing program structure.

In Figure 1, I show the s_{min} dependence of the total cross section and of the two component subprocesses. Clearly, the calculation is well behaved for any value of s_{min} below approximately 30 GeV^2. Above that value, the resolution parameter interferes with the jet algorithm and forces excessive parton clustering. As expected, good statistical accuracy is more difficult to obtain at small values of s_{min}.

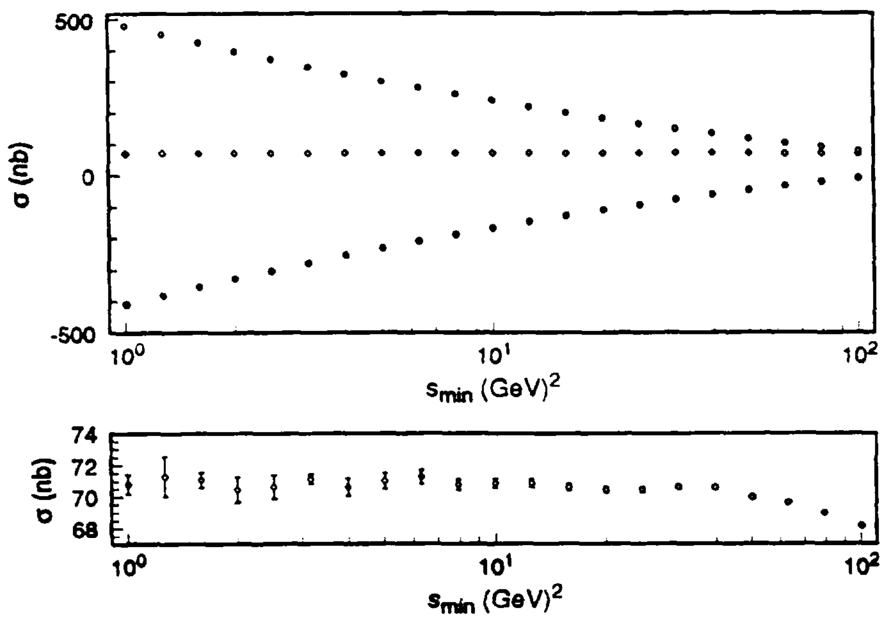

Figure 1: a) s_{min} dependence of the total cross section (center), $gg \to gggg$ sub-process (top) and $gg \to ggg$ sub-process (bottom). b) Expanded view of the s_{min} dependence of the total cross section.

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